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TECHNICAL REPORT 3139

EVALUATION  
OF  
LOW TEMPERATURE TEST PROCEDURES  
FOR  
ELECTROEXPLOSIVE DEVICES

LEONARD SHAINHEIT

COPY 65 OF 67

MARCH 1964

434831

PICATINNY ARSENAL  
DOVER, NEW JERSEY

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OF  
LOW TEMPERATURE TEST PROCEDURES  
FOR  
ELECTROEXPLOSIVE DEVICES

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MARCH 1964

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## INTRODUCTION

Constant current sensitivity data, for ambient temperature conditions, are available for M6 Electric Blasting Caps, (Figure 1) as detailed in Reference 1. To further characterize the sensitivity of this blasting cap, it was decided to conduct Brucceton constant current sensitivity tests at a low temperature (-40°F).

Usually, in work of this type, the item is removed from the conditioning apparatus and placed in a firing chamber for functioning. Because the item under test may warm between the time it is removed from the conditioning box and fired, a study was initiated to ascertain if such a procedure provides valid low temperature information. This study resulted in the development of a modified test procedure -- the caps were insulated using "styrofoam" to prevent their warming significantly prior to fire -- to insure that reliable low temperature data would be obtained.

This report summarizes the results of the investigation and reports the low temperature (-40°F) sensitivity characteristics of the M6 Blasting Cap. Lot 1, manufactured by Company A, was used.



#### SUMMARY

Five Bruceton constant current staircase sensitivity tests were performed at -40°F on M6 Electric Blasting Caps using pulse times of 0.001, 0.010, 0.100, 1.000 and 10.000 seconds. A technique, which utilized insulated caps to guarantee maintenance of low temperature after the caps were removed from the conditioning box for firing, was employed in these tests (Table 1).

Further sensitivity tests were conducted on Lot 1 at ambient temperature and at low temperatures in accordance with the low temperature test procedures outlined in MIL-S-45428A -- no insulation is used to protect the caps from warming rapidly, once removed from the conditioning chamber. A summary of these results is in Table 2. Certain results from Table 1 are included for comparison purposes.

The current estimates in the two low temperature tests appear to differ appreciably.

The most significant result in Test 3 -- testing under dynamic conditions the items warmed rapidly -- was the very small spread in high and low fire probability levels compared to the spread for the other two tests (testing under stable conditions, either no or only slight temperature change). This result is the antithesis of what was expected.

#### CONCLUSIONS

Low temperature tests conducted in accordance with the procedures outlined in such military specifications as MIL-S-45428A are inadequate for the proper evaluation of electroexplosive devices (EEDs).

Low temperature testing of initiators can be properly accomplished if the items are functioned in the low temperature atmosphere or adequately insulated so that the test temperature can be maintained if they are removed from the conditioning chamber prior to test.

#### RECOMMENDATIONS

Low temperature testing of initiators should be effected in the low temperature conditioning atmosphere or, if this is not possible, the initiators should be properly insulated so that test temperature can be maintained if the EEDs are removed from the conditioning apparatus prior to test.

Low temperature test procedures outlined in military specifications pertaining to EEDs should be revised in such a manner so as to specify that the items be tested while maintained at the conditioning temperature.

## STUDY

M6 Blasting Caps, taken from Lot 1 manufactured by Company A, were subjected to constant current staircase tests at -40°F, using five different pulse times -- 0.001, 0.010, 0.100, 1.000 and 10.000 seconds. The test results are summarized in Table 3; detailed results are in Tables 4-8.

It can be seen from Table 3 that as the pulse width was lengthened (that is, as the pulse time increased), the necessary firing current decreased -- in all but one case. This was at the 10-second pulse at 99.9% reliability, which was higher than the corresponding value for the 1-second and 0.1-second pulse. Apparently, this result is not unusual although the phenomenon is, as evidenced by similar reports on findings pertaining to sensitivity of initiators, by The Franklin Institute Laboratories and Picatinny Arsenal (Reference 1). No satisfactory explanation is available for this occurrence and no attempt at theorizing will be made.

The standard deviation is usually indicative of lot uniformity. The smaller the standard deviation or spread, the more uniform the lot. It may be noted that the value shown for the 10-second pulse time (0.04073 log ma) is large. However, this is not unusual. Long pulse times permit functioning of a given item over a wide range of time for the same input current. For example, M6 Caps were actuated at 285 ma inasmuch as 2,366 msec and as little as 234 msec (Table 8). This creates inconsistencies and large standard deviations. The Bruceton tests were accomplished employing the Franklin Institute Laboratory Universal Pulser (FILUP). The FILUP is capable of providing a predetermined quantity of current for a specified time (the pulse width).

Further information pertaining to the Bruceton method is in Reference 2.

To facilitate fuze design, two graphs (Figure 2 and 3) were prepared so that the relationship between current energy and time at -40°F for the M6 Cap may be more readily determined. Figure 2 shows the relationship between the 0.1%, 50% and 99.9% firing currents and pulse time. The 0.1% and 99.9% firing levels were calculated at 90% confidence. The relationship between the firing energy for 99.9% reliability at 90% confidence and time of application of this energy is plotted in graph form (Figure 3). The equation employed for calculating the required energy for a given firing probability was:

$$W = I^2 R t$$

"I" equals the current at the 99.9% fire with 90% confidence.

"R" equals resistance (assumed to be about 1.7 ohms which was a relatively high value for the M6 Caps tested

"t" equals time of pulse duration.

These curves, based on data obtained at  $-40^{\circ}\text{F}$ , have nearly the same shape as those shown in Picatinny Arsenal Technical Report 104 (for data obtained at ambient temperature).

Sometimes EEDs which pass low temperature performance tests, conducted in accordance with military specifications, fail when used under field conditions. The procedure commonly used for testing the M6 Cap at low temperature permits testing of conditioned items in an ambient temperature atmosphere. This means that the caps may actually be fired at other than the specified low temperatures. To determine the suitability of such methods, an investigation into low temperature test procedures was conducted. Since M6 Caps are relatively brisant, firing within expensive conditioning apparatus is undesirable or precluded altogether. However, it was still essential to simulate the test temperature as nearly as possible so that meaningful data could be obtained. To accomplish this, the blasting caps were contained in 1x1x4-inches styrofoam insulation. This insulating material was chosen on the basis of an investigation performed before the sensitivity test program. A brief description is given below.

Several thermocouples were calibrated in the following manner: They were placed in a conditioning chamber maintained at  $-65^{\circ}\text{F}$  for 16 hours. Then the thermocouples were connected to a Brush Recorder and the voltage at  $-65^{\circ}\text{F}$  obtained. The temperature in the chamber was lowered and the equilibrium voltage recorded. This technique was continued until sufficient data was obtained so that a graph could be plotted relating EMF to temperature. This procedure was repeated on each thermocouple. Figure 4 shows the relationship between EMF and temperature for one thermocouple.

The blasting caps contained in styrofoam insulation were conditioned at  $-40^{\circ}\text{F}$  for 16 hours, removed individually and allowed to warm to ambient temperature. By means of the calibrated thermocouples, the relationship between warm-up time and temperature was determined. Figure 5 shows one of the typical curves. This graph shows that the caps experience only a slight temperature rise during the two minute warm-up interval after removal from the conditioning chamber. The temperature increase

per unit time for the first two minutes after removal was 0.016 °F per second. Consequently, it was concluded that near conditioning temperatures could be maintained if the insulated caps were fired rapidly -- preferably in less than two minutes after removal from the conditioning chamber. Further tests were conducted on M6 Caps, taken from Lot 1 at ambient temperature and also at low temperatures by following the low temperature test procedures outlined in MIL-S-45428A as applied to the M6 Cap. The test results are reported in Table 9 and 10. Examination of these tables and Table 2 reveal that the current estimated to obtain a 99.9% firing reliability at 90% confidence level as well as for the 50% firing point is higher at cold temperatures (-40°F) than at ambient temperatures. This data also shows that the current values estimated for the 0.1% firing point at the 90% confidence level did not differ at these two temperature conditions. The value for the mean or 50% firing points lay somewhere between the corresponding values obtained in the other two tests. Furthermore, the estimated current for the 0.1% fire at 90% confidence was higher in this test (Test 3) than the corresponding values calculated from the data in Test 1 and 2. It should be noted also, that the calculated current for the 99.9% fire at 90% confidence was lower in Test 3 than the corresponding values obtained in Test 1 and 2. Observe also that the current range between the 99.9% point and 0.1% point at the 90% confidence level is narrow or the standard deviation for this test is smaller than that in either of the other two. Test 3 was conducted while the caps were in the process of warming toward ambient temperature. It could be that this unstable condition (brought about by rapid warming which possibly led to physical or transitional changes in the explosive charges and to thermal expansions and contractions which in turn could have produced thermal stresses) was responsible for the unusual data in Test 3.

Statistically, it can be shown that there is a significant difference between the mean obtained in the test performed at -40°F and that obtained in the test conducted in accordance with the low temperature test methods described in MIL-S-45428A. A statistical comparison of these means at the 1% and 5% significance levels is in Appendix C.

Care should be taken in conducting initiator sensitivity and output tests at extreme temperatures, to insure that the initiator is maintained at the desired test temperature. Certain insulating materials are adequate for this purpose. It may even be more desirable to build barricades into conditioning equipment so that testing in the chamber may be effected.

#### REFERENCES

1. E. L. Miller, Current Sensitivity of M6 Blasting Caps (U), Artillery Ammunition and Research Development Laboratory Report 104 (CONFIDENTIAL), Picatinny Arsenal, March 1962.
2. Statistical Analysis for a New Procedure in Sensitivity Experiments, Statistical Research Group, Princeton University, July 1944.

APPENDICES

APPENDIX A

TABLES



TABLE 1

SUMMARY OF CONSTANT CURRENT SENSITIVITY TESTS CONDUCTED  
AT -40°F ON THE M6 ELECTRIC BLASTING CAP \*

Pulse Time (sec)	50% Firing Reliability (ma)	90% Confidence Level	
		99.9% Firing Reliability (ma)	0.1% Firing Reliability (ma)
0.001	1,530	1,950	1,210
0.010	575	753	438
0.100	331	372	294
1.000	281	244	308
10.000	273	410	158

\* The M6 Caps were taken from Company A, Lot 1.

The caps were insulated to insure maintenance of the low temperature during the warm-up period between the time they were removed from the conditioning apparatus and functioned.

TABLE 2

SUMMARY OF BRUCETON CONSTANT CURRENT SENSITIVITY  
TESTS CONDUCTED ON THE M6 BLASTING CAP, LOT 1  
(0.01-Sec Pulse)

	Reliability, %		
	Confidence Level		
Test	99.9 (ma)	0.1 (ma)	50% (ma)
1 (A.T.)*	627	438	524
2 (-40°F)**	753	438	575
3 (-40°F Spec)***	597	491	542

\* A.T. - ambient temperature (78°F)

\*\* The M6 Caps were insulated, using 1"x1"x4" styrofoam to insure maintenance of low temperatures when fired in ambient temperature atmosphere.

\*\*\* The test was conducted in accordance with the low temperature test procedures outlined in MIL-S-45428A using the maximum warm-up time of two minutes before fire. These caps were not insulated.

TABLE 3

SUMMARY OF CALCULATED TESTS OF FIVE BRUCETON CONSTANT  
CURRENT SENSITIVITY TESTS CONDUCTED AT -40°F ON M6  
BLASTING CAPS FROM COMPANY A, LOT 1

Pulse Time (sec)	Mean or 50% Firing Point		90% Confidence Level					
			99.9% Reliability		0.1% Reliability		Standard Time Energy	
			ma	log ma	ma	log ma	Deviation	Level
	ma	log ma	ma	log ma	ma	log ma	log ma	(watt-sec)
0.001	1,530	3.18469	,950	3.29003	1,210	3.08279	0.02235	0.0046
0.010	575	2.75926	753	2.87689	438	2.64163	0.02567	0.0085
0.100	331	2.51930	372	2.56997	294	2.46863	0.01003	0.0208
1.000	281	2.44799	322	2.50794	244	2.38804	0.01488	0.1556
10.000	273	2.43539	419	2.62252	158	2.19846	0.04073	2.6340

The caps were insulated to insure maintenance of the low temperature during the warm-up period between the time they were removed from the conditioning apparatus and functioned.

APPENDIX B

FIGURES

TABLE 4

RESULTS OF CONSTANT CURRENT STAIRCASE SENSITIVITY TEST  
ON  
M6 ELECTRIC BLASTING CAPS AT -40°F, LOT 1 FROM  
COMPANY A  
(0.001-Second Pulse)

Item	Resistance (ohms)	Functioning Time (msec)	Firing Current (amp)	Functioning Time at Destruct current (msec)*	Fire (X) No-Fire (O)
1	1.61	---	1.61	8.1	O
2	1.52	8.7	1.68	---	X
3	1.47	---	1.61	7.8	O
4	1.52	Lost	1.68	---	X
5	1.52	6.6	1.61	---	X
6	1.56	8.6	1.53	---	X
7	1.24	---	1.46	Lost	O
8	1.56	---	1.53	9.3	O
9	1.51	10.3	1.61	---	X
10	1.49	---	1.53	7.4	O
11	1.58	6.6	1.61	---	X
12	1.52	10.7	1.53	---	X
13	1.59	10.8	1.46	---	X
14	1.57	---	1.39	Lost	O
15	1.53	---	1.46	6.6	O
16	1.57	8.6	1.53	---	X
17	1.58	---	1.46	6.3	O
18	1.54	---	1.53	7.3	O
19	1.59	12.6	1.61	---	X
20	1.47	9.4	1.53	---	X
21	1.47	---	1.46	5.8	O
22	1.53	---	1.53	6.2	O
23	1.53	7.8	1.61	---	X
24	1.49	---	1.53	7.0	O
25	1.54	8.8	1.61	---	X
26	1.67	Lost	1.53	---	X
27	1.57	Lost	1.46	---	X
28	1.54	---	1.39	6.2	O
29	1.51	---	1.46	6.2	O
30	1.59	---	1.53	5.6	O
31	1.63	6.2	1.61	---	X
32	1.51	---	1.53	6.5	O
33	1.51	---	1.61	8.9	O
34	1.57	9.0	1.68	---	X
35	1.56	10.0	1.61	---	X
36	1.54	8.1	1.53	---	X
37	1.60	---	1.46	6.1	O
38	1.55	10.5	1.53	---	X
39	1.58	---	1.46	7.4	O
40	1.55	7.4	1.53	---	X
41	1.47	---	1.46	5.9	O
42	1.53	12.5	1.53	---	X
43	1.51	---	1.46	7.0	O
44	1.54	---	1.53	6.4	O
45	1.57	9.2	1.61	---	X
46	1.55	---	1.53	7.2	O
47	1.50	8.5	1.61	---	X
48	1.60	---	1.53	6.7	O

NOTE: \*Failures were destroyed at 2 amps.  
Line R = 0.08 ohm  
Log Interval = 0.02 log amp

The caps were insulated to insure maintenance of the low temperature during the warm-up period between the time they were removed from the conditioning apparatus and functioned.

TABLE 5

RESULTS OF CONSTANT CURRENT STAIRCASE SENSITIVITY TEST  
ON  
M6 ELECTRIC BLASTING CAPS AT -40°F, LOT 1 FROM  
COMPANY A  
(0.01-Second Pulse)

Item	Resistance (ohm)	Functioning Time (msec)	Firing Current (ma)	Functioning Time at Destruct Current (msec)*	Fire (X) No-Fire (O)
1	1.57	9.88	646	-----	X
2	1.55	9.88	603	-----	X
3	1.48	-----	563	10.02	O
4	1.60	9.87	603	-----	X
5	1.61	-----	563	9.87	O
6	1.48	9.88	603	-----	X
7	1.46	-----	563	9.87	O
8	1.53	-----	603	9.88	O
9	1.50	11.50	646	-----	X
10	1.62	9.89	603	-----	X
11	1.57	-----	563	9.88	O
12	1.55	10.66	603	-----	X
13	1.54	-----	563	9.88	O
14	1.56	9.87	603	-----	X
15	1.54	9.87	563	-----	X
16	1.58	9.89	525	-----	X
17	1.58	-----	490	9.87	O
18	1.55	-----	525	9.88	O
19	1.55	-----	563	9.88	O
20	1.53	9.88	603	-----	X
21	1.54	-----	563	9.88	O
22	1.52	-----	603	9.89	O
23	1.50	9.88	646	-----	X
24	1.53	9.87	603	-----	X
25	1.57	-----	563	9.90	O
26	1.56	9.90	603	-----	X
27	1.67	9.88	563	-----	X
28	1.63	-----	525	9.89	O
29	1.58	9.89	563	-----	X
30	1.46	-----	525	9.89	O
31	1.56	-----	563	9.89	O
32	1.54	9.89	603	-----	X
33	1.49	-----	563	9.89	O
34	1.55	9.88	603	-----	X
35	1.64	-----	563	9.89	O
36	1.59	-----	603	9.90	O
37	1.50	9.88	646	-----	X
38	1.46	9.88	603	-----	X
39	1.54	10.37	563	-----	X
40	1.51	-----	525	9.89	O
41	1.60	9.88	563	-----	X
42	1.54	-----	525	9.88	O
43	1.57	-----	563	9.89	O
44	1.59	10.09	525	-----	X
45	1.55	-----	563	9.88	O
46	1.61	9.87	603	-----	X
47	1.53	-----	563	10.68	O
48	1.52	9.88	603	-----	X
49	1.56	9.87	563	-----	X
50	1.54	-----	525	9.87	O

\* Failures were destroyed at 1 amp.

Line R = 0.08 ohm

Log Interval = 0.03 log ma

The caps were insulated to insure maintenance of the low temperature during the warm-up period between the time they were removed from the conditioning apparatus and functioned.

TABLE 6

RESULTS OF CONSTANT CURRENT STAIRCASE SENSITIVITY TEST  
ON  
M6 ELECTRIC BLASTING CAPS AT -40°F, LOT 1 FROM  
COMPANY A  
(0.1-Second Pulse)

Item	Resistance (ohm)	Functioning Time (msec)	Firing Current (ma)	Functioning Time at Destruct Current (msec)*	Fire (X) No-Fire (O)
1	1.50	-----	328	7.71	O
2	1.56	-----	340	6.90	O
3	1.56	72.74	352	-----	X
4	1.58	93.70	340	-----	X
5	1.55	55.77	328	-----	X
6	1.53	-----	317	7.52	O
7	1.47	-----	328	7.89	O
8	1.61	90.29	340	-----	X
9	1.59	87.49	328	-----	X
10	1.56	-----	317	8.29	O
11	1.54	90.23	328	-----	X
12	1.57	-----	317	8.73	O
13	1.56	100.52	328	-----	X
14	1.55	-----	317	7.18	O
15	1.56	-----	328	8.14	O
16	1.58	88.37	340	-----	X
17	1.56	-----	328	7.85	O
18	1.64	73.37	340	-----	X
19	1.61	92.00	328	-----	X
20	1.51	-----	317	8.57	O
21	1.53	-----	328	7.49	O
22	1.64	63.82	340	-----	X
23	1.57	-----	328	7.81	O
24	1.58	90.44	340	-----	X
25	1.58	-----	328	6.25	O
26	1.62	95.95	340	-----	X
27	1.55	-----	328	7.88	O
28	1.52	97.54	340	-----	X
29	1.59	-----	328	7.25	O
30	1.57	-----	340	7.42	O
31	1.51	67.92	352	-----	X
32	1.55	78.86	340	-----	X
33	1.57	88.33	328	-----	X
34	1.45	-----	317	7.21	O
35	1.55	-----	328	6.10	O
36	1.64	87.20	340	-----	X
37	1.54	-----	328	7.09	O
38	1.60	102.33	340	-----	X
39	1.52	105.71	328	-----	X
40	1.61	-----	317	7.20	O
41	1.53	101.45	328	-----	X
42	1.48	-----	317	6.91	O
43	1.52	91.21	328	-----	X
44	1.56	-----	317	7.32	O
45	1.50	-----	328	7.20	O
46	1.57	109.80	340	-----	X

\* Failures were destroyed at 1 amp  
Line R = 0.08 ohm  
Log Interval = 0.015 log ma

The caps were insulated to insure maintenance of the low temperature during the warm-up period between the time they were removed from the conditioning apparatus and functioned.

TABLE 7

RESULTS OF CONSTANT CURRENT STAIRCASE SENSITIVITY TEST  
ON  
M6 ELECTRIC BLASTING CAPS AT -40°F, LOT 1 FROM  
COMPANY A  
(1-Second Pulse)

Item	Resistance (ohm)	Functioning Time (msec)	Firing Current (ma)	Functioning Time at Destruct Current (msec)*	Fire (X) No-Fire (O)
1	1.53	-----	257	8.56	O
2	1.55	-----	266	9.93	O
3	1.56	-----	276	6.98	O
4	1.48	1,225	285	-----	X
5	1.57	747	276	-----	X
6	1.48	-----	266	11.13	O
7	1.55	540	276	-----	X
8	1.55	-----	266	10.52	O
9	1.52	662	276	-----	X
10	1.54	-----	266	7.93	O
11	1.51	583	276	-----	X
12	1.51	-----	266	7.76	O
13	1.51	-----	276	8.19	O
14	1.57	-----	285	7.70	O
15	1.49	301	295	-----	X
16	1.46	309	285	-----	X
17	1.42	-----	276	8.54	O
18	1.55	460	285	-----	X
19	1.42	-----	276	9.58	O
20	1.46	922	285	-----	X
21	1.52	-----	276	7.21	O
22	1.44	877	285	-----	X
23	1.51	-----	276	8.41	O
24	1.49	-----	285	8.59	O
25	1.48	347	295	-----	X
26	1.57	522	285	-----	X
27	1.53	754	276	-----	X
28	1.60	---	266	7.47	O
29	1.48	536	276	-----	X
30	1.50	---	266	8.25	O
31	1.56	575	276	-----	X
32	1.54	---	266	7.88	O
33	1.52	---	276	9.68	O
34	1.54	538	285	-----	X
35	1.53	---	276	9.36	O
36	1.42	---	285	7.75	O
37	1.46	528	295	-----	X
38	1.41	---	285	8.98	O
39	1.50	730	295	-----	X
40	1.45	555	285	-----	X
41	1.58	---	276	8.39	O
42	1.49	---	285	8.24	O
43	1.43	521	295	-----	X
44	1.42	---	285	9.01	O
45	1.62	293	295	-----	X
46	1.57	547	285	-----	X
47	1.53	---	276	7.94	O
48	1.51	---	285	8.61	O
49	1.57	400	295	-----	X
50	1.54	634	285	-----	X

\* Failures were destroyed at 1 amp

Line R = 0.08 ohm

Log Interval = 0.015 log ma

The caps were insulated to insure maintenance of the low temperature during the warm-up between the time they were removed from the conditioning apparatus and functioned.



TABLE 8

RESULTS OF CONSTANT CURRENT STAIRCASE SENSITIVITY TEST  
ON  
M6 ELECTRIC BLASTING CAPS AT -40°F, LOT 1 FROM  
COMPANY A  
(10-Second Pulse)

Item	Resistance (ohm)	Functioning Time (msec)	Firing Current (ma)	Functioning Time at Destruct Current (msec)*	Fire (X) No-Fire (O)
1	1.53	748	266	----	X
2	1.59	-----	257	8.89	O
3	1.55	-----	266	7.91	O
4	1.52	-----	276	7.36	O
5	1.50	654	285	-----	X
6	1.41	-----	276	7.92	O
7	1.55	2,366	285	-----	X
8	1.54	411	276	-----	X
9	1.50	-----	266	8.06	O
10	1.53	-----	276	Lost	O
11	1.50	258	285	-----	X
12	1.59	708	276	-----	X
13	1.43	-----	266	7.41	O
14	1.56	-----	276	9.82	O
15	1.52	555	285	-----	X
16	1.50	-----	276	9.90	O
17	1.57	836	285	-----	X
18	1.54	-----	276	7.60	O
19	1.47	646	285	-----	X
20	1.47	-----	276	8.68	O
21	1.48	781	285	-----	X
22	1.55	-----	276	7.71	O
23	1.59	234	285	-----	X
24	1.50	798	276	-----	X
25	1.40	-----	266	7.40	O
26	1.68	-----	276	6.98	O
27	1.53	1,510	285	-----	X
28	1.51	1,594	276	-----	X
29	1.48	-----	266	8.80	O
30	1.56	-----	276	8.24	O
31	1.50	-----	285	7.76	O
32	1.65	549	295	-----	X
33	1.45	-----	285	7.15	O
34	1.51	493	295	-----	X
35	1.48	642	285	-----	X
36	1.48	-----	276	8.77	O
37	1.53	437	285	-----	X
38	1.54	439	276	-----	X
39	1.59	-----	266	6.89	O
40	1.51	1,116	276	-----	X
41	1.58	-----	266	8.27	O
42	1.53	871	276	-----	X
43	1.56	-----	266	7.77	O
44	1.51	-----	276	7.73	O
45	1.64	641	285	-----	X
46	1.56	423	276	-----	X
47	1.57	346	266	-----	X
48	1.53	-----	257	8.32	O
49	1.47	-----	266	7.63	O
50	1.66	396	276	-----	X

\* Failures were destroyed at 1 amp.  
Line R = 0.08 ohm  
Log Interval = 0.015 log ma

The caps were insulated to insure maintenance of the low temperature during the warm-up period between the time they were removed from the conditioning apparatus and functioned.

TABLE 9

RESULTS OF CONSTANT CURRENT STAIRCASE SENSITIVITY TEST  
 AT AMBIENT TEMPERATURE, ON M6 ELECTRIC BLASTING CAP  
 FROM LOT 1, COMPANY A  
 (0.010-Second Pulse)

Item	Resistance (ohms)	Functioning Time (msec)	Firing Current (m amp)	Functioning Time at Destruct Current (msec)*	Fire (X) No-Fire (O)
1	1.65	11.65	603	----	X
2	1.66	15.90	563	----	X
3	1.65	15.25	525	----	X
4	1.73	17.30	490	----	X
5	1.66	-----	458	6.73	O
6	1.70	-----	490	6.21	O
7	1.61	-----	525	6.12	O
8	1.65	12.80	563	----	X
9	1.63	-----	525	6.00	O
10	1.66	13.26	563	----	X
11	1.62	-----	525	5.18	O
12	1.62	12.62	563	----	X
13	1.65	14.84	525	----	X
14	1.60	-----	490	6.59	O
15	1.67	-----	525	6.69	O
16	1.64	14.18	563	----	X
17	1.64	14.34	525	----	X
18	1.70	-----	490	6.48	O
19	1.63	16.69	525	----	X
20	1.63	-----	490	5.71	O
21	1.62	-----	525	5.61	O
22	1.60	13.62	563	----	X
23	1.66	-----	525	5.47	O
24	1.58	12.36	563	----	X
25	1.67	-----	525	9.32	O
26	1.60	13.15	563	----	X
27	1.60	-----	525	6.66	O
28	1.70	13.64	563	----	X
29	1.56	13.30	525	----	X
30	1.60	-----	490	6.96	O
31	1.62	15.43	525	----	X
32	1.60	-----	990	6.61	O
33	1.63	17.59	525	----	X
34	1.58	-----	490	6.32	O
35	1.62	13.90	525	----	X
36	1.55	-----	490	6.31	O
37	1.60	-----	525	6.33	O
38	1.66	12.19	563	----	X
39	1.67	15.22	525	----	X
40	1.66	-----	490	6.26	O
41	1.62	-----	525	6.54	O
42	1.60	15.08	563	----	X
43	1.63	-----	525	5.57	O
44	1.61	17.06	563	----	X
45	1.60	14.14	525	----	X
46	1.69	-----	490	5.73	O
47	1.60	15.14	525	----	X
48	1.59	-----	490	6.03	O
49	1.58	-----	525	6.39	O
50	1.56	14.22	563	----	X
51	1.68	17.97	525	----	X

\* Failures were destroyed at 1 amp  
 Line R = 0.08 ohm  
 Log Interval = 0.03 log mamp

TABLE 10

RESULTS OF CONSTANT CURRENT STAIRCASE SENSITIVITY TEST IN  
 ACCORDANCE WITH THE LOW TEMPERATURE TEST PROCEDURES  
 OUTLINED IN MIL-S-45428A ON THE M6 ELECTRIC BLASTING CAP  
 FROM LOT 1, COMPANY A  
 (0.010-Second Pulse)

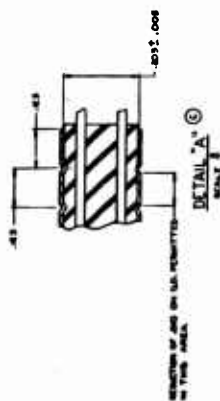
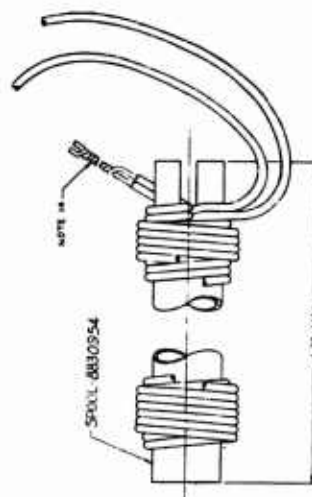
Item	Resistance (ohms)	Functioning Time (msec)	Firing Current (mamp)	Functioning Time at Destruct Current (msec)*	Fire (X) No-Fire (O)
1	1.62	-----	514	7.73	0
2	1.52	-----	525	8.19	0
3	1.62	-----	538	7.21	0
4	1.53	16.98	550	-----	X
5	1.56	15.79	538	-----	X
6	1.62	-----	525	8.37	0
7	1.59	-----	538	7.61	0
8	1.61	16.56	550	-----	X
9	1.64	14.99	538	-----	X
10	1.54	-----	525	7.13	0
11	1.62	-----	538	7.00	0
12	1.55	-----	550	7.43	0
13	1.58	13.68	568	-----	X
14	1.61	-----	550	6.93	0
15	1.63	14.31	563	-----	X
16	1.66	15.90	550	-----	X
17	1.59	15.32	563	-----	X
18	1.70	-----	550	9.06	0
19	1.60	14.51	538	-----	X
20	1.57	-----	525	6.42	0
21	1.73	15.28	538	-----	X
22	1.57	-----	525	9.48	0
23	1.62	-----	538	8.01	0
24	1.62	15.09	550	-----	X
25	1.55	-----	538	7.47	0
26	1.57	18.06	550	-----	X
27	1.59	-----	538	8.71	0
28	1.55	-----	550	7.07	0
29	1.59	13.99	563	-----	X
30	1.59	15.91	550	-----	X
31	1.56	-----	538	6.81	0
32	1.62	14.26	550	-----	X
33	1.62	12.96	538	-----	X
34	1.52	-----	525	7.53	0
35	1.49	-----	538	6.20	0
36	1.64	13.80	550	-----	X
37	1.57	-----	538	7.63	0
38	1.67	13.94	550	-----	X
39	1.59	15.10	538	-----	X
40	1.53	-----	525	7.81	0
41	1.57	-----	538	6.71	0
42	1.56	16.44	550	-----	X
43	1.51	-----	538	7.31	0
44	1.49	-----	550	7.47	0
45	1.57	13.53	563	-----	X
46	1.58	-----	550	6.59	0
47	1.53	15.09	563	-----	X
48	1.78	13.06	550	-----	X
49	1.51	15.61	538	-----	X
50	1.54	-----	525	6.94	0
51	1.67	13.49	538	-----	X

\* Failures were destroyed at 1 amp.

Line R = 0.08 ohm

Log Interval = 0.03 Log mamp

The caps were conditioned for 16 hours at -40°F prior to removal from the cold chamber and allowed to warm at ambient temperature for two minutes before actuation.

[illegible]

14 - THE MENTION CABLE SHALL BE FITTED WITH THE PLUG ASSEMBLY AT A PRESSURE SUFFICIENT TO CONSOLIDATE THE CABLE WITHOUT EXCESSIVE BEALAGE OF BRIDGE WIRES

- ② - The distance to the nearest building was to be taken from the nearest building.
- ③ - The distance to the nearest building was to be taken from the nearest building.
- ④ - The distance to the nearest building was to be taken from the nearest building.
- ⑤ - The distance to the nearest building was to be taken from the nearest building.
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- ⑦ - The distance to the nearest building was to be taken from the nearest building.
- ⑧ - The distance to the nearest building was to be taken from the nearest building.
- ⑨ - The distance to the nearest building was to be taken from the nearest building.
- ⑩ - The distance to the nearest building was to be taken from the nearest building.

SEE DRAVING BOARD FOR ALTERNATIVE

NO 137 OF 1972, 200

NO. 137 OF 1973, 200

UNCLASSIFIED DATE OF DECLASS 08 OCT 97 NO 8836972 ②

[illegible]

**CAP, BLASTING,  
ELECTRIC**

[illegible]

2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050	2051	2052	2053	2054	2055	2056	2057	2058	2059	2060	2061	2062	2063	2064	2065	2066	2067	2068	2069	2070	2071	2072	2073	2074	2075	2076	2077	2078	2079	2080	2081	2082	2083	2084	2085	2086	2087	2088	2089	2090	2091	2092	2093	2094	2095	2096	2097	2098	2099	2100	2101	2102	2103	2104	2105	2106	2107	2108	2109	2110	2111	2112	2113	2114	2115	2116	2117	2118	2119	2120	2121	2122	2123	2124	2125	2126	2127	2128	2129	2130	2131	2132	2133	2134	2135	2136	2137	2138	2139	2140	2141	2142	2143	2144	2145	2146	2147	2148	2149	2150	2151	2152	2153	2154	2155	2156	2157	2158	2159	2160	2161	2162	2163	2164	2165	2166	2167	2168	2169	2170	2171	2172	2173	2174	2175	2176	2177	2178	2179	2180	2181	2182	2183	2184	2185	2186	2187	2188	2189	2190	2191	2192	2193	2194	2195	2196	2197	2198	2199	2200	2201	2202	2203	2204	2205	2206	2207	2208	2209	2210	2211	2212	2213	2214	2215	2216	2217	2218	2219	2220	2221	2222	2223	2224	2225	2226	2227	2228	2229	2230	2231	2232	2233	2234	2235	2236	2237	2238	2239	2240	2241	2242	2243	2244	2245	2246	2247	2248	2249	2250	2251	2252	2253	2254	2255	2256	2257	2258	2259	2260	2261	2262	2263	2264	2265	2266	2267	2268	2269	2270	2271	2272	2273	2274	2275	2276	2277	2278	2279	2280	2281	2282	2283	2284	2285	2286	2287	2288	2289	2290	2291	2292	2293	2294	2295	2296	2297	2298	2299	2300	2301	2302	2303	2304	2305	2306	2307	2308	2309	2310	2311	2312	2313	2314	2315	2316	2317	2318	2319	2320	2321	2322	2323	2324	2325	2326	2327	2328	2329	2330	2331	2332	2333	2334	2335	2336	2337	2338	2339	2340	2341	2342	2343	2344	2345	2346	2347	2348	2349	2350	2351	2352	2353	2354	2355	2356	2357	2358	2359	2360	2361	2362	2363	2364	2365	2366	2367	2368	2369	2370	2371	2372	2373	2374	2375	2376	2377	2378	2379	2380	2381	2382	2383	2384	2385	2386	2387	2388	2389	2390	2391	2392	2393	2394	2395	2396	2397	2398	2399	2400	2401	2402	2403	2404	2405	2406	2407	2408</
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Figure 1

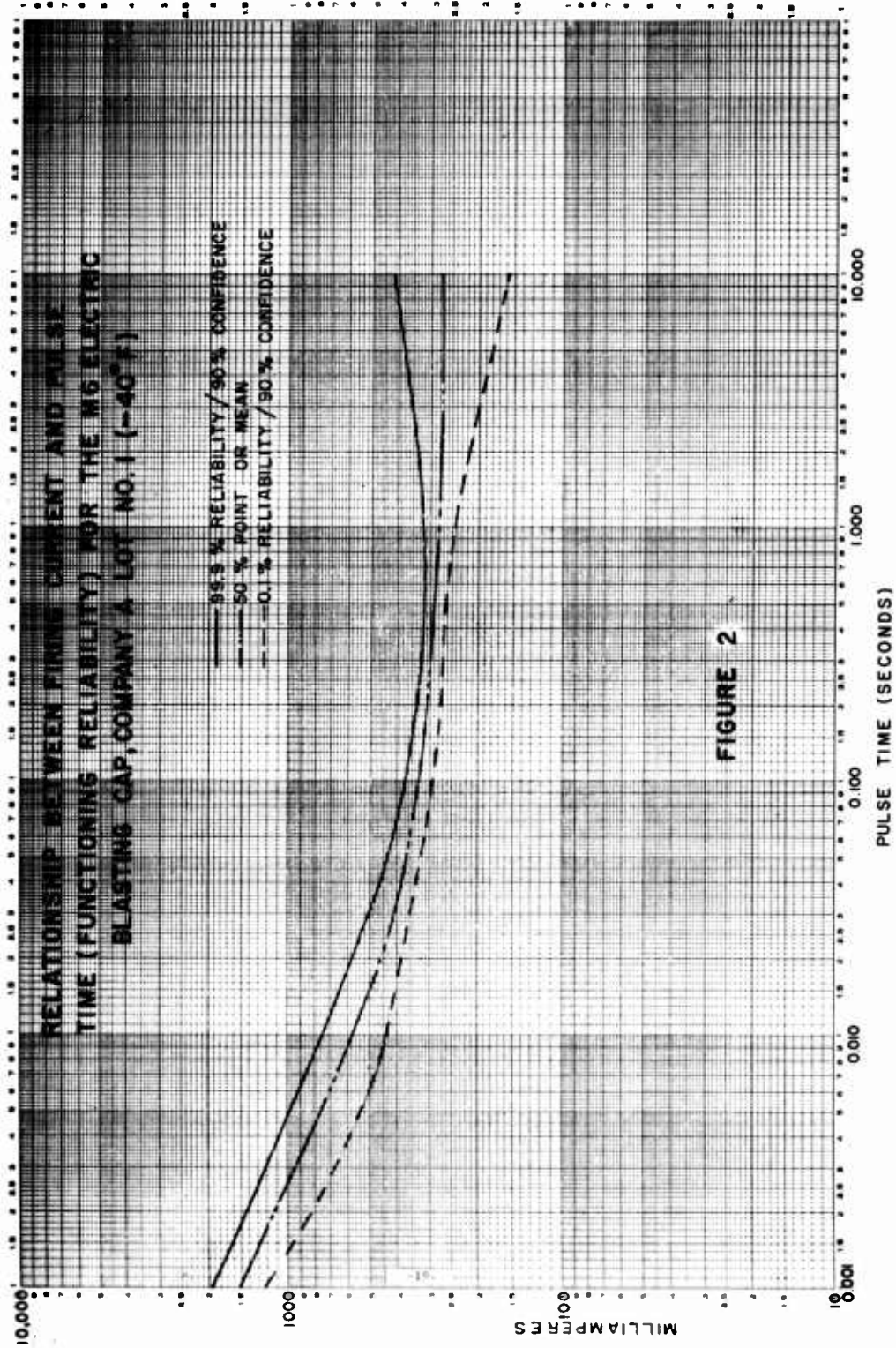
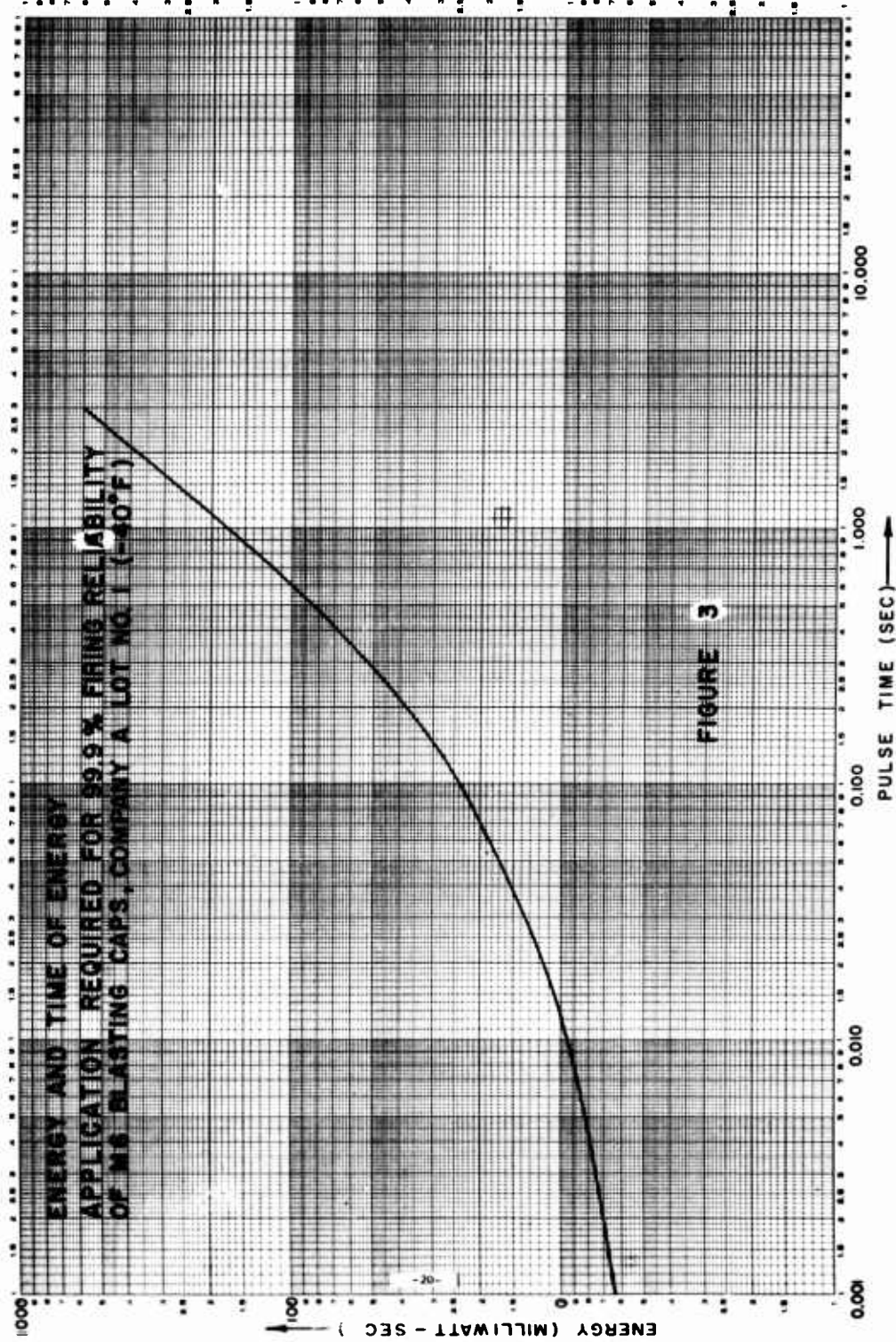
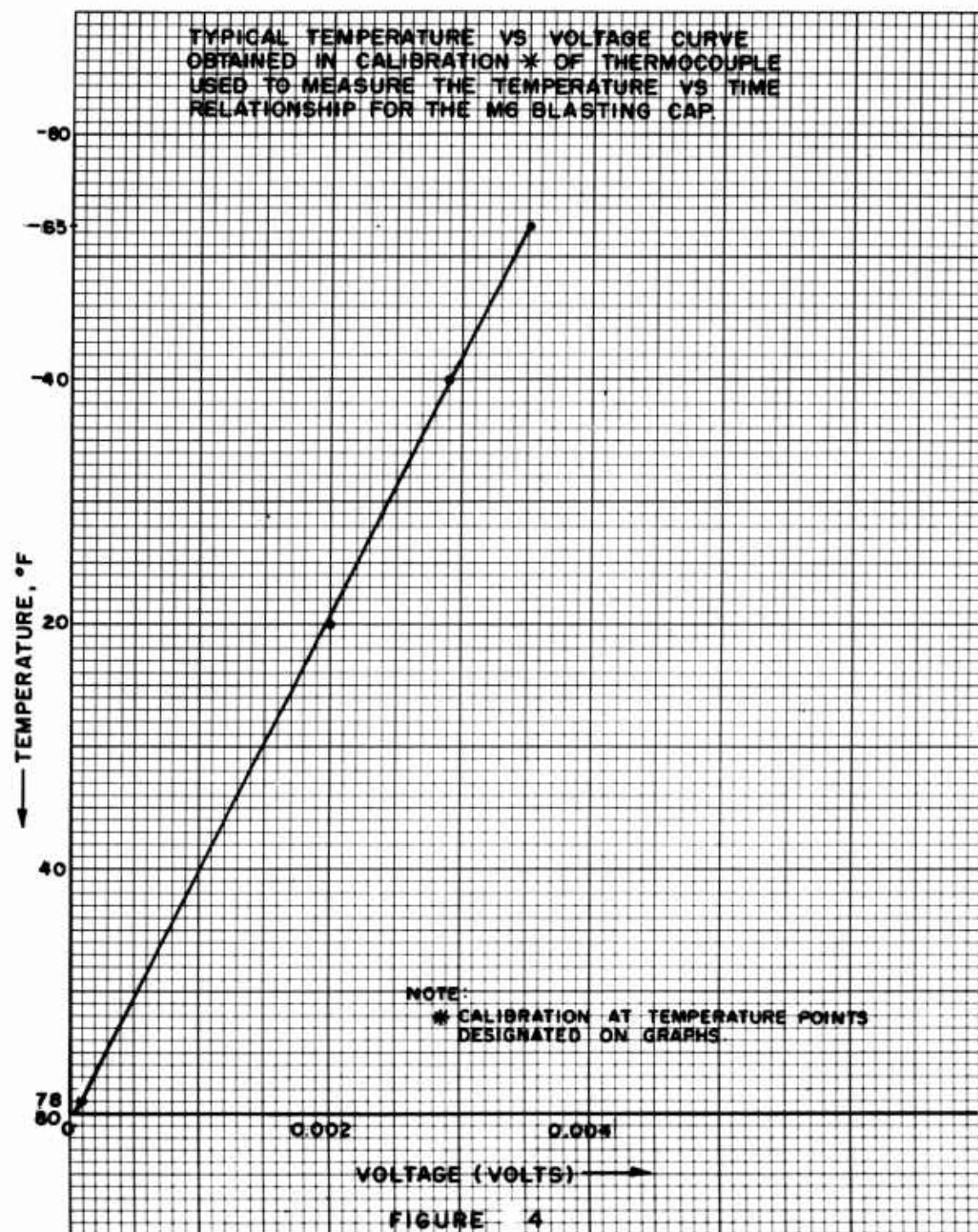
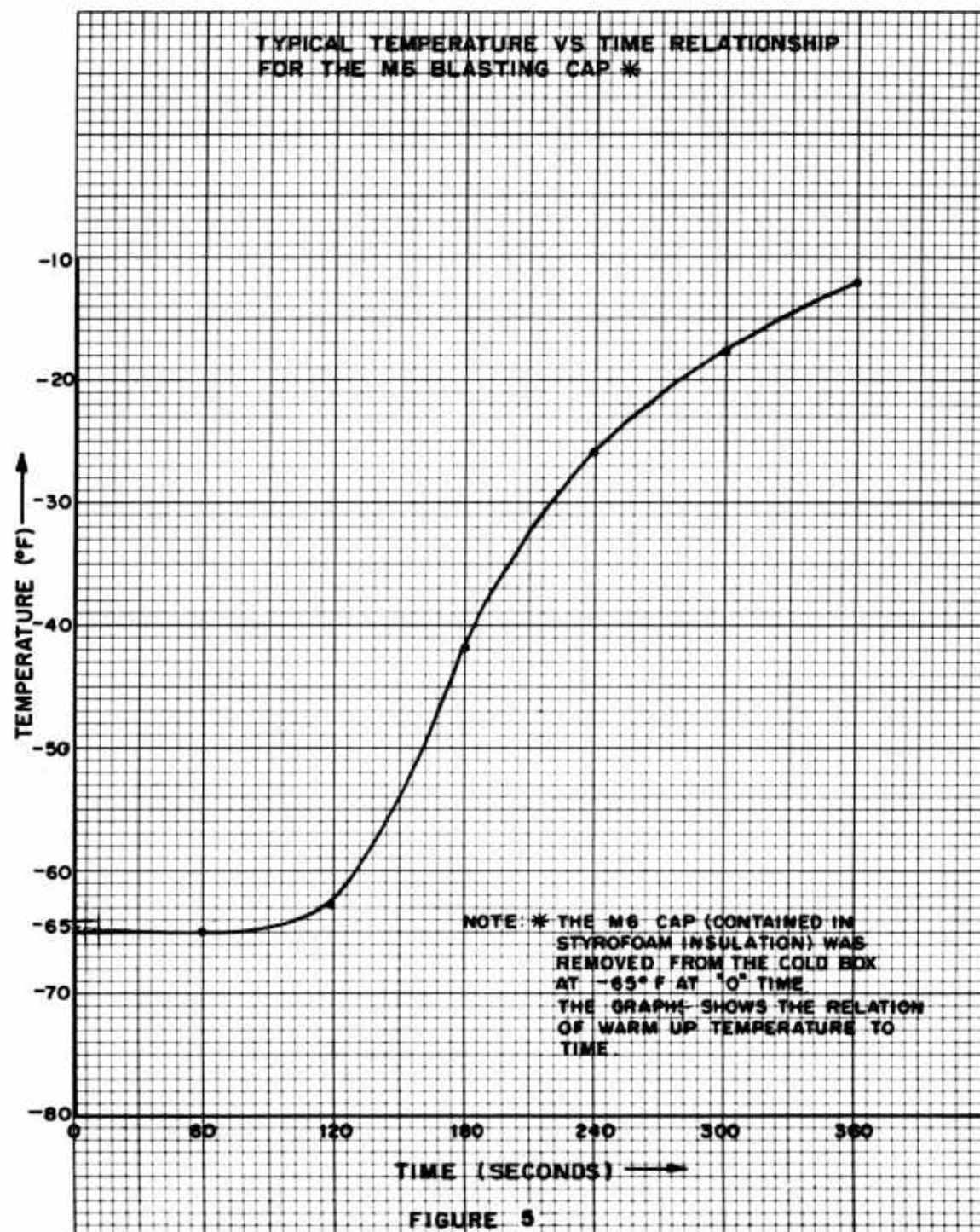


FIGURE 2











APPENDIX C  
CALCULATIONS

I. BRUCETON CONSTANT CURRENT SENSITIVITY TESTS ON THE  
M6 ELECTRIC BLASTING CAP

A. Test Conducted at -40°F

1. Calculation of the Mean (m) or 50% Firing Reliability:

$$m = c + d \left( \frac{1}{N_i} \sum i f_i + \frac{1}{2} \right)$$

Where  $m$  = mean in log units

$c$  = lowest normalized firing current (log units)

$d$  = step size in log units

$N_i$  = total number of fires or no-fires (use the smaller of the two values)

$f_i$  = number of fires or no-fires (whichever occurs in fewer numbers) at a given current level

$i$  = current level; 0, 1, 2, 3, .....

a. 0.001-Second Pulse

<u>log amp</u>	<u>amp</u>	<u>i</u>	<u><math>f_x</math></u>	<u><math>f_o</math></u>	<u><math>i f_o</math></u>	<u><math>i^2 f_o</math></u>
0.14435	1.39	0	20	2	0	0
0.16435	1.46	1	3	9	9	9
0.18435	1.53	2	10	10	20	40
0.20435	1.61	3	11	3	0	27
0.22435	1.68	4	3	0	0	0

$$N_x = 27$$

$$N_o = 24$$

$$\sum i f_o = 38$$

$$\sum i^2 f_o = 76$$

$$m = 0.14435 + 0.02 \left( \frac{1}{24} \times 38 + \frac{1}{2} \right)$$

$$m = 0.186016 \text{ log amp} \quad 1.53 \text{ amp}$$

b. 0.010-Second Pulse

<u>log</u>	<u>ma</u>	<u>i</u>	<u>f<sub>x</sub></u>	<u>f<sub>o</sub></u>	<u>if<sub>o</sub></u>	<u>i<sup>2</sup>f<sub>o</sub></u>
2.69051	490	0	0	1	0	0
2.72051	525	1	1	6	6	6
2.75051	563	2	6	14	28	56
2.78051	603	3	15	3	9	27
2.81051	646	4	4	0	0	0

$$N_x = 26$$

$$N_o = 24$$

$$\sum if_o = 43$$

$$\sum i^2 f_o = 89$$

$$m = 2.69051 + 0.03 \left( \frac{1}{24} (43) + \frac{1}{2} \right)$$

$$m = 2.75926 \log ma \sim 574.5 \text{ ma}$$

c. 0.100-Second Pulse

<u>log ma</u>	<u>ma</u>	<u>i</u>	<u>f<sub>o</sub></u>	<u>f<sub>x</sub></u>	<u>f<sub>x</sub></u>	<u>i<sup>2</sup>f<sub>x</sub></u>
2.50137	317	0	9	0	0	0
2.51637	328	1	12	9	9	9
2.53137	340	2	2	12	24	48
2.54637	352	3	0	2	6	18

$$N_x = 23$$

$$N_o = 23$$

$$\sum if_o = 39$$

$$\sum i^2 f_o = 75$$

$$m = 2.50137 + 0.015 \left( \frac{1}{23} \times 39 - \frac{1}{2} \right)$$

$$m = 2.51930 \log ma \sim 330.6 \text{ ma}$$

d. 1.000-Second Pulse

<u>log ma</u>	<u>ma</u>	<u>i</u>	<u>f<sub>x</sub></u>	<u>f<sub>o</sub></u>	<u>if<sub>x</sub></u>	<u>i<sup>2</sup>f<sub>x</sub></u>
2.42549	266	0	0	8	0	0
2.44049	276	1	7	10	7	7
2.45549	285	2	10	7	20	40
2.47049	295	3	7	0	21	63

$$N_x = 24$$

$$N_o = 25$$

$$\sum if_x = 48$$

$$\sum i^2 f_x = 110$$

$$m = 2.42549 + 0.015 \left( \frac{1}{24} \times 48 - \frac{1}{2} \right)$$

$$m = 2.44799 \log ma \sim 281 \text{ ma}$$

e. 10.000-Second Pulse

<u>log ma</u>	<u>ma</u>	<u>i</u>	<u>f<sub>o</sub></u>	<u>f<sub>x</sub></u>	<u>if<sub>o</sub></u>	<u>i<sup>2</sup>f<sub>o</sub></u>
2.41040	257	0	2	0	0	0
2.42549	266	1	9	2	9	9
2.44049	276	2	12	0	24	48
2.45549	285	3	2	12	6	18
2.47049	295	4	0	2	0	0

$$N_x = 25$$

$$N_o = 25$$

$$\sum if_o = 29$$

$$\sum i^2 f_o = 75$$

$$m = 2.41049 + 0.015 \left( \frac{1}{25} \times 29 - \frac{1}{2} \right)$$

$$m = 2.43539 \log ma \sim 273 \text{ ma}$$

2. Calculation of M

$$M = \frac{\sum f_i^2}{N_i} - \left( \frac{\sum f_i}{N_i} \right)^2$$

The symbols have the same meaning as for estimating m.

a. 0.001-Second Pulse

$$M = \frac{76}{24} - \left( \frac{38}{24} \right)^2$$

$$M = 0.6608$$

b. 0.010-Second Pulse

$$M = \frac{89}{24} - \left( \frac{43}{24} \right)^2$$

$$M = 0.50$$

c. 0.100-Second Pulse

$$M = \frac{75}{53} - \left( \frac{39}{23} \right)^2$$

$$M = 0.386$$

d. 1.000-Second Pulse

$$M = \frac{110}{24} - \left( \frac{48}{24} \right)^2$$

$$M = 0.583$$

e. 10.000-Second Pulse

$$M = \frac{75}{25} - \left( \frac{29}{25} \right)^2$$

$$M = 1.65$$

### 3. Determination of Constant S

Values of S are posted in Table I of the Princeton Report (Page 51) and correspond to the value of M calculated above. Interpolation of values may have been necessary but will not be shown.

<u>Pulse Time</u> <u>(sec)</u>	<u>S</u>
0.001	1.118
0.010	0.856
0.100	0.669
1.000	0.992
10.000	2.715

### 4. Calculation of the Standard Deviation $\sigma_m$

$$\sigma_m = dS$$

Where:

$$\sigma_m = \text{standard deviation in log units}$$

Both d and S have the same meanings as before

#### a. 0.001-Second Pulse

$$\sigma_m = 0.02 \times 1.118$$

$$\sigma_m = 0.02235 \text{ log amp}$$

#### b. 0.010-Second Pulse

$$\sigma_m = 0.03 \times 0.856$$

$$\sigma_m = 0.025668 \text{ log ma}$$

#### c. 0.100-Second Pulse

$$\sigma_m = 0.015 \times 0.669$$

$$\sigma_m = 0.01003 \text{ log ma}$$

#### d. 1.000-Second Pulse

$$\sigma_m = 0.015 \times 0.992$$

$$\sigma_m = 0.01488 \text{ log ma}$$

#### e. 10.000-Second Pulse

$$\sigma_m = 0.015 \times 2.715$$

$$\sigma_m = 0.04073 \text{ log ma}$$

### 5. Determination of the Constants G and H

Values of G are obtained from Graph IV and H from Graph IV of the Princeton Report (Pages 56 and 57). Interpolation of values may have been necessary but will not be shown.

<u>Pulse Time (sec)</u>	<u>G</u>	<u>H</u>
0.001	0.99	1.43
0.010	1.01	1.33
0.100	1.05	1.27
1.000	1.00	1.38
10.000	0.93	1.96

### 6. Calculation of Standard Error,

$$\sigma_p = \sigma_m \sqrt{\frac{G^2 + K^2 H^2}{N_i}}$$

where:  $\sigma_p$  is the standard error in log units

K is a constant for the desired reliability (3.090 for 99.9% reliability)

The other values are as described above

#### a. 0.001-Second Pulse

$$\sigma_p = \frac{0.02235 \sqrt{(0.99)^2 + (3.090)^2 (1.425)^2}}{\sqrt{24}}$$

$$\sigma_p = 0.02061 \text{ log amp}$$

#### b. 0.010-Second Pulse

$$\sigma_p = \frac{0.02567 \sqrt{(1.01)^2 + (3.090)^2 (1.33)^2}}{\sqrt{24}}$$

$$\sigma_p = 0.02218 \text{ log ma}$$

c. 0.100-Second Pulse

$$\sigma_p = \frac{0.01003 \sqrt{(1.05)^2 \times (3.090)^2 (1.27)^2}}{\sqrt{23}}$$

$$\sigma_p = 0.01137 \log ma$$

d. 1.000-Second Pulse

$$\sigma_p = \frac{0.01488 \sqrt{(1.00)^2 + (3.090)^2 (1.38)^2}}{\sqrt{24}}$$

$$\sigma_p = 0.01330 \log ma$$

e. 10.000-Second Pulse

$$\sigma_p = \frac{0.04073 \sqrt{10.9253^2 + (3.090)^2 (1.96)^2}}{\sqrt{25}}$$

$$\sigma_p = 0.05 \log ma$$

7. Calculation of the 99.9% and 0.1% Firing Reliability for a 50% Confidence Level (F99.9/50 and F0.1/50)

$$F_{99.9/50} = M + K\sigma_m$$

$$F_{0.1/50} = M - K\sigma_m$$

Where:  $F_{99.9/50}$  are in log units  
 $m$ ,  $k$  and  $\sigma_m$  have been defined above

a. 0.001-Second Pulse

$$F_{99.9/50} = 0.18602 + 3.090 (0.02235)$$

$$F_{99.9/50} = 0.25508 \log amp$$

$$F_{0.1/50} = 0.18602 - 3.090 (0.02235)$$

$$F_{0.1/50} = 0.11694 \log amp$$



b. 0.010-Second Pulse

$$F99.9/50 = 2.75926 + 3.090 (0.02567)$$

$$F99.9/50 = 2.83858 \log ma$$

$$FO.1/50 = 2.75926 - 3.090 (0.02567)$$

$$FO.1/50 = 2.67994 \log ma$$

c. 0.100-Second Pulse

$$F99.9/50 = 2.51930 + 3.090 (0.01003)$$

$$F99.9/50 = 2.55029 \log ma$$

$$FO.1/50 = 2.51930 - 3.090 (0.01003)$$

$$FO.1/50 = 2.48831 \log ma$$

d. 1.000-Second Pulse

$$F99.9/50 = 2.44799 + 3.090 (0.01488)$$

$$F99.9/50 = 2.49397 \log ma$$

$$FO.1/50 = 2.44799 - 3.090 (0.01488)$$

$$FO.1/50 = 2.40201 \log ma$$

e. 10.000-Second Pulse

$$F99.9/50 = 2.41049 + 3.090 (0.04072)$$

$$F99.9/50 = 2.53632 \log ma$$

$$FO.1/50 = 2.41049 - 3.090 (0.04072)$$

$$FO.1/50 = 2.28466 \log ma$$

8. Calculation of the 99.9% and 0.1% Firing Reliability for a 90% Confidence Level (F99.9/90 and FO.1/90)

$$F99.9/90 = F99.9/50 + K \left( \frac{N1 + 1.2}{N1} \right) \sigma_p$$

$$FO.1/90 = FO.1/50 - K \left( \frac{N1 + 1.2}{N1} \right) \sigma_p$$

Where: F99.9/90 and FO.1/90 are in log units

K is a constant for the desired confidence  
(1.645 for 90% confidence)

All other values are as defined above

a. 0.001-Second Pulse

$$F99.9/90 = 0.25508 + 1.645 \left( \frac{24 + 1.2}{24} \right) 0.02061$$

$$F99.9/90 = 0.29068 \log \text{ amp} \sim 1.95 \text{ amp}$$

$$FO.1/90 = 0.11694 - 1.645 \left( \frac{24 + 1.2}{24} \right) 0.02061$$

$$F99.9/90 = 0.29068 \log \text{ amp} \sim 1.95 \text{ amp}$$

$$FO.1/90 = 0.11694 - 1.645 \left( \frac{24 + 1.2}{24} \right) 0.02061$$

$$FO.1/90 = 0.08134 \log \text{ amp} \sim 1.21 \text{ amp}$$

b. 0.010-Second Pulse

$$F99.9/90 = 2.83858 + 1.645 \left( \frac{24 + 1.2}{24} \right) 0.02218$$

$$F99.9/90 = 2.83858 \log \text{ ma} \sim 753 \text{ ma}$$

$$FO.1/90 = 2.67994 - 1.645 \left( \frac{24 + 1.2}{24} \right) 0.02218$$

$$FO.1/90 = 2.64163 \log \text{ ma} \sim 438 \text{ ma}$$

c. 0.100-Second Pulse

$$F_{99.9/90} = 2.55029 + 1.645 \left( \frac{23 + 1.2}{23} \right) 0.01137$$

$$F_{99.9/90} = 2.56997 \log ma \sim 372 \text{ ma}$$

$$F_{0.1/90} = 2.48831 - 1.645 \left( \frac{23 + 1.2}{23} \right) 0.01137$$

$$F_{99.9/90} = 2.56997 \log ma \sim 372 \text{ ma}$$

$$F_{0.1/90} = 2.48831 - 1.645 \left( \frac{23 + 1.2}{23} \right) 0.01137$$

$$F_{0.1/90} = 2.46863 \log ma \sim 294 \text{ ma}$$

d. 1.000-Second Pulse

$$F_{99.9/90} = 2.49397 + 1.645 \left( \frac{24 + 1.2}{24} \right) 0.01330$$

$$F_{99.9/90} = 2.50794 \log ma \sim 322 \text{ ma}$$

$$F_{0.1/90} = 2.40201 - 1.645 \left( \frac{24 + 1.2}{24} \right) 0.01330$$

$$F_{0.1/90} = 2.38804 \log ma \sim 244 \text{ ma}$$

e. 10.000-Second Pulse

$$F_{99.9/90} = 2.53632 + 1.645 \left( \frac{25 + 1.2}{25} \right) 0.05$$

$$F_{99.9/90} = 2.62252 \log ma \sim 410 \text{ ma}$$

$$F_{0.1/90} = 2.28466 - 1.645 \left( \frac{25 + 1.2}{25} \right) 0.05$$

$$F_{0.1/90} = 2.19846 \log ma \sim 158 \text{ ma}$$

B. Test Conducted at Ambient Temperature

1. Calculation of the Mean (m) or 50% Firing Reliability (0.01 Second Pulse)

<u>log ma</u>	<u>ma</u>	<u>i</u>	<u>f<sub>o</sub></u>	<u>f<sub>x</sub></u>	<u>if<sub>o</sub></u>	<u>i<sup>2</sup>f<sub>o</sub></u>
2.66055	458	0	1	0	0	0
2.69051	490	1	11	1	11	11
2.72051	525	2	12	12	24	48
2.75051	563	3	0	13	0	0

$$N_x = 26$$

$$N_o = 24$$

$$\sum if_o = 35$$

$$\sum i^2 f_o = 39$$

$$m = 2.66055 + 0.03 \left( \frac{1}{24} \times 35 + 0.5 \right)$$

$$m = 2.71930 \log ma \sim 524 \text{ ma}$$

2. Calculation of M

$$M = \frac{59}{24} - \left( \frac{35}{24} \right)^2 = 0.3316$$

3. Determination of Constant S

See Page 51 of the Princeton Report

$$S = 0.5749$$

4. Calculation of the Standard Deviation,  $\sigma_m$ .

$$\sigma_m = 0.03 \times 0.575 = 0.01725 \log ma$$

5. Determination of the Constants G and H

See Pages 56 and 57 of the Princeton Report

$$G = 1.11$$

$$H = 1.29$$

6. Calculation of the Standard Error,  $\sigma_p$

$$\sigma_p = 0.01725 \sqrt{\frac{(1.11)^2 + (3.09)^2 + (1.29)^2}{24}}$$

$$\sigma_p = 0.01415 \log ma$$

7. Calculation of the 99.9% and 0.1% Firing Reliability for a 50% Confidence Level (F99.9/50 and FO.1/50)

$$F_{99.0/50} = 2.71930 + 3.090 (0.01725)$$

$$= 2.77260 \log ma$$

$$F_{0.1/50} = 2.71930 - 3.090 (0.01725)$$

$$= 2.66600 \log ma$$

8. Calculation of the 99.9% and 0.1% Firing Reliabilities for a 90% Confidence Level (F99.9/90 and FO.1/90)

$$F_{99.9/90} = 2.77260 + 1.645 \left( \frac{24 + 1.2}{24} \right) 0.01415$$

$$= 2.79704 \log ma \sim 625 ma$$

$$F_{0.1/90} = 2.66600 - 1.645 \left( \frac{24 + 1.2}{24} \right) 0.01415$$

$$= 2.64162 \log ma \sim 438 ma$$

C. Test Conducted at Low Temperature in Accordance with MIL-S-45428A

1. Calculation of the Mean (m) or 50% Firing Reliability (0.01 Second Pulse)

<u>log ma</u>	<u>ma</u>	<u>i</u>	<u>fo</u>	<u>fx</u>	<u>ifo</u>	<u>i<sup>2</sup>fo</u>
2.72051	525	0	9	0	0	0
2.73051	538	1	11	9	11	11
2.74051	550	2	5	11	10	20
2.75051	563	3	0	5	0	0

$$N_x = 25$$

$$N_o = 25$$

$$\sum i f_o = 21$$

$$\sum i^2 f_o = 31$$

$$m = 2.72051 + 0.01 \left( \frac{1}{25} \times 21 + 0.5 \right)$$

$$m = 2.73391 \log ma$$

2. Calculation of M

$$M = \frac{31}{25} - \left( \frac{21}{25} \right)^2 = 0.53440$$

3. Determination of Constant S

See Page 51 of the Princeton Report

$$S = 0.93153$$

4. Calculation of the Standard Deviation,  $\sigma_m$

$$\sigma_m = 0.01 \times 0.932$$

$$\sigma_m = 0.00932 \log ma$$

5. Determination of the Constants G and H

See Pages 56 and 57 of the Princeton Report

$$G = 1.013$$

$$H = 1.36$$

6. Calculation of the Standard Error,  $\sigma_p$

$$\sigma_p = 0.00932 \sqrt{\frac{(1.013)^2 + (3.09)^2 + (1.36)^2}{25}}$$

$$\sigma_p = 0.01082 \log ma$$

7. Calculation of the 99.9% and 0.1% Firing Reliability  
for a 50% Confidence Level (F99.9/50 and F0.1/50)

$$F99.9/50 = 2.73391 + 3.090 (0.00932)$$

$$= 2.76269 \log ma$$

$$F0.1/50 = 2.73391 - 3.090 (0.00932)$$

$$= 2.70513 \log ma$$

8. Calculation of the 99.9% and 0.1% Firing Reliability  
for a 50% Confidence Level (F99.9/90 and F0.1/90)

$$F99.9/90 = 2.76269 + 1.645 \left( \frac{25 + 1.2}{25} \right) 0.01082$$

$$= 2.69125 \log ma \sim 491 ma$$

II. REQUIRED ENERGY (W) FOR A 99.9% FIRING RELIABILITY  
AT A 90% CONFIDENCE LEVEL FOR THE M6 ELECTRIC  
BLASTING CAP AT -40°F

$$W = I^2 R t$$

where: W = energy in mwatt-sec

I = current F99.9/90 in amps

R = assumed bridge resistance of 1.7 ohms

t = pulse time in msec

a. 0.001-Second Pulse

$$W = (1.95)^2 \times 1.7 \times 0.001$$

$$W = 6.46 \text{ mwatt secs}$$

b. 0.010-Second Pulse

$$W = (0.753)^2 \times 1.7 \times 0.010$$

$$W = 0.64 \text{ mwatt-secs}$$

c. 0.100-Second Pulse

$$W = (0.372)^2 \times 1.7 \times 0.100$$

$$W = 23.5 \text{ mwatt-secs}$$

d. 1.000-Second Pulse

$$W = (0.322)^2 \times 1.7 \times 1$$

$$W = 176.3 \text{ mwatt-secs}$$

e. 10.000-Second Pulse

$$W = (0.419)^2 \times 1.7 \times 10$$

$$W = 2,985 \text{ mwatt-secs}$$



III. COMPARISON OF THE MEANS OBTAINED FOR THE M6 BLASTING CAP  
AT -40°F (INSULATED CAPS) AND IN ACCORDANCE WITH THE LOW  
TEMPERATURE TEST PROCEDURES OUTLINED IN MIL-S-45428A

a. 1% Significance Level

$$\sigma_{\sigma} = \frac{\sigma_m G}{\sqrt{N}} \quad \text{where } \sigma_{\sigma} \text{ is the standard error of the estimated mean.}$$

$\sigma_m$ , G and N have the same definitions given above

$$1. \quad \frac{-40^{\circ}\text{F}}{\sigma_{\sigma_1}} = \frac{\sigma_{m_1} G_1}{\sqrt{N_1}} = \frac{0.025668 \times 1.01}{\sqrt{24}}$$

$$\sigma_{\sigma_1} = 0.005292 \log ma$$

$$m_1 = 2.75926 \log ma$$

2. Low Temperature Test as per MIL-S-45428A

$$\sigma_{\sigma_2} = \frac{\sigma_{m_2} G_2}{\sqrt{N_2}} = \frac{0.00932 \times 1.013}{\sqrt{24}}$$

$$\sigma_{\sigma_2} = 0.001927 \log ma$$

$$m_2 = 2.73391 \log ma$$

$$m_1 - m_2 = 2.75926 - 2.73391$$

$$\Delta m = 0.02535 \log ma$$

$$\text{If } \Delta m > (2.58) \frac{N + 2.9}{N} \sqrt{\sigma_{\sigma_1}^2 + \sigma_{\sigma_2}^2}$$

then  $m_1$  is significantly different than  $m_2$ . Since,

$$0.02535 > (2.58) \left( \frac{24 + 2.9}{24} \right) \sqrt{(0.005292)^2 + (0.001927)^2}$$

or  $0.02535 > 0.016286$ , then  $M_1$  and  $M_2$  are

significantly different

b. 5% Significance Level

1. -40°F

$$\sigma_{\sigma_1} = \frac{\sigma_{m_1} G_1}{\sqrt{N_1}} = 0.005292 \log ma$$

$$M_1 = 2.75926 \log ma$$

c. 2. Low Temperature Test as per MIL-S-45428A

$$\sigma_{\sigma_2} = \frac{\sigma_{m_2} G_2}{\sqrt{N_2}} = 0.001927 \log ma$$

$$m_2 = 2.73391 \log ma$$

$$\Delta m = m_1 - m_2 = 0.02535 \log ma$$

$$\text{If } \Delta m > (1.96) \left( \frac{N + 2.2}{N} \right) \sqrt{\sigma_{\sigma_1}^2 + \sigma_{\sigma_2}^2}$$

then  $m_1$  is significantly different than  $m_2$ .

$$\text{Since, } 0.025352 > (1.96) \left( \frac{24 + 2.2}{24} \right) \sqrt{(0.005292)^2 + (0.001927)^2}$$

or  $0.02535 > 0.01205$ , then  $m_1$  and  $m_2$  are

significantly different

ABSTRACT DATA

# ABSTRACT

Accession No. AD

Picatinny Arsenal, Dover, New Jersey

## EVALUATION OF LOW TEMPERATURE TEST PROCEDURES FOR ELECTROEXPLOSIVE DEVICES

Leonard Shainheit

Technical Report 3139, March 1964, 43 pp,  
tables, figures. UNCLASSIFIED report from  
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Ammunition Engineering Directorate.

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To further characterize the sensitivity of  
this blasting cap, Bruceton constant current  
sensitivity tests at low temperature, were  
conducted.

Usually, in work of this type, the item  
is removed from the conditioning apparatus  
and placed in a firing chamber for  
functioning. Because the item under test  
may warm between the time it is removed  
from the conditioning box and fired, a study  
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procedure provides valid low temperature  
information.

This report summarizes the results of  
the investigation and reports the low  
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the M6 Blasting Cap.

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1. Explosives Initiators -  
Electroexplosive  
devices
2. Evaluation of Low  
Temperature Test  
Procedures for  
Electroexplosive  
Devices

I. Shainheit, Leonard

## UNITERMS

M6 Electric Blasting  
Cap  
Bruceton Tests  
Insulated caps  
MIL-S-45428A  
Electroexplosive  
devices  
Initiators  
Pulse width  
Thermocouples  
Explosive charges  
Thermal expansions  
Shainheit, L.

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Electroexplosive devices  
Initiators  
Pulse width

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Accession No. \_\_\_\_\_ AD \_\_\_\_\_

Picatinny Arsenal, Dover, New Jersey

**EVALUATION OF LOW TEMPERATURE TEST PROCEDURES FOR ELECTROEXPLOSIVE DEVICES**

*Leonard Shainheit*

Technical Report 3139, March 1964, 43 pp. tables, figures.  
Unclassified report from the Artillery Ammunition Laboratory, Ammunition Engineering Directorate.

Constant current sensitivity data, for ambient temperature conditions, were available for M6 Electric Blasting Caps. To further characterize the sensitivity of this blasting cap, Brucceton constant current sensitivity tests at low temperature, were conducted.

(over)

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1. Explosives Initiators - Electroexplosive devices
2. TITLE

1. Shainheit, Leonard

UNITERMS

M6

Brucceton Tests  
Insulated caps  
MIL-S-45428A  
Electroexplosive devices  
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Usually, in work of this type, the item is removed from the conditioning apparatus and placed in a firing chamber for functioning. Because the item under test may warm between the time it is removed from the conditioning box and fired, a study was initiated to ascertain if such a procedure provides valid low temperature information.

This report summarizes the results of the investigation and reports the low temperature sensitivity characteristics of the M6 Blasting Cap.

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Thermal expansions  
Shainheit, L.  
Electric  
Blasting  
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